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TRANSLATIONS FROM GIGIYENA I SANITARIYA

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SOME FACTS ON NATURAL ENVIRONMENTAL RADIOACTIVITY  
CAUSED BY THE PRESENCE OF K-40

[Following is a translation of an article by V. I. Ryadov and N. V. Petrukhin in the Russian periodical Gigiyena i Sanitariya (Hygiene and Sanitation), Vol. 27, No. 9, 1962, pages 30-34.]

In order to make a sanitary-hygienic appraisal of radioactive contamination of a locality, it is important to know both the total activity and the portion attributable to artificial (fission-fragment) activity. Yet some studies (V. N. Gus'kova, A. N. Bragina, 1958; L. S. Apel', 1959) contain data only on the total activity of the soil and food products. This makes it difficult to determine the extent to which the fragmental activity of a given environmental object exceeds natural activity.

Natural radioactive isotopes are present in soil, vegetation, food products, and in the organs and tissues of animals and man. Most of the natural radioactivity of the soil is caused by K-40 ( $2.1 \cdot 10^{-8}$  curies/kg). Soil radioactivity due to the presence of Rb-87, Ra-226, Th-232, and U-238 is 10 to 100 times less. Soil radioactivity from other natural isotopes ranges from  $10^{-12}$  to  $10^{-22}$  curies/kg and has no practical significance. It appears that the natural activity of the

soil is mainly determined by radioactive potassium. This applies particularly to soil lacking a high content of heavy elements (Ra-226, Th-232, U-238).

Investigation of the content of K-40, Rb-87, Ra-226, Th-232, and U-238 in plants (Table 1) reveals that there are still greater differences in the concentrations of potassium and the other isotopes both in relative quantities and in activity. Activity in plants due to potassium is 100 to 1000 times higher than that due to rubidium, radium, thorium, and uranium. The difference is even greater in the activity caused by potassium and radium in animal products (Table 2).

**Table 1**  
**Content of Certain Natural Radioactive Isotopes in Plants**

| 1                 | 2                                    | 3   | 4  |
|-------------------|--------------------------------------|---|--|
| Изотоп            | Содержание элемента в растении (в %) | Литературный источник                             | Активность изотопа в растении (в кюри/кг)      |
| K <sup>40</sup>   | 0,12—0,94                            | И. М. Кузнецов<br>Г. Д. Магидов<br>А. В. Соколов  | 0,90—7,6·10 <sup>-9</sup>                      |
| Rb <sup>87</sup>  | 10 <sup>-4</sup>                     | Атомная энергия                                   | 1,8·10 <sup>-11</sup>                          |
| Ra <sup>226</sup> | 10 <sup>-11</sup> —10 <sup>-12</sup> | (краткая энциклопедия).<br>Госнадат ВСЭ, стр. 139 | 10 <sup>-10</sup> —10 <sup>-11</sup>           |
| Th <sup>232</sup> | 10 <sup>-5</sup> —10 <sup>-6</sup>   |   | 1,16·10 <sup>-11</sup> —1,16·10 <sup>-12</sup> |
| U <sup>238</sup>  | 10 <sup>-5</sup> —10 <sup>-6</sup>   |   | 3,31·10 <sup>-11</sup> —3,31·10 <sup>-12</sup> |

10 - 1 Рассчитана нами.

- 1 - Isotope
- 2 - Content of element in plants (as %)
- 3 - Published source
- 4 - Isotope activity in plants (as %)

- 5 - I. M. Kuznetsov
- 6 - G. D. Magidov
- 7 - A. V. Sokolov
- 8 - Atomic energy
- 9 - (Short Encyclopedia). Gosizdat Large Sov. Encyc., p. 139
- 10 - Calculated by ourselves

**Table 2**

**Potassium and Radium Content of Animal Products**

| 1<br>Продукт | 2<br>Изотоп       | 3<br>Содержание элемента<br>(в г на 1 кг про-<br>дукта) | 4<br>Литературный<br>источник | 5<br>Активность изотопа<br>(в кури/кг) <sup>1</sup> |
|--------------|-------------------|---|-------------------------------|---|
| 6 Молоко     | K <sup>40</sup>   | 1,27  | Л. С. Штен-<br>берг и др.     | 1,0·10 <sup>-9</sup>                                |
|              | Ra <sup>226</sup> | 0,04—2,7·10 <sup>-13</sup>                              | Ф. В. Спирс                   | 0,04—2,7·10 <sup>-13</sup>                          |
|              | K <sup>40</sup>   | 2,71  | К. С. Петров-<br>ский         | 2,2·10 <sup>-9</sup>                                |
| 7 Мясо       | Ra <sup>226</sup> | 8,0·10 <sup>-13</sup>                                   | Ф. В. Спирс                   | 8,0·10 <sup>-13</sup>                               |

<sup>1</sup> 2 - Рассчитана нами.

- |  |                                |
|--|--------------------------------|
| 1 - Product  | 7 - Meat                       |
| 2 - Isotope  | 8 - L. S. Shtenberg and others |
| 3 - Content of element<br>(in g per kg of product)   | 9 - F. W. Spiers               |
| 4 - Published source                                 | 10 - K. S. Petrovskiy          |
| 5 - Isotope activity<br>(in curies/kg <sup>1</sup> ) | 11 - F. W. Spiers              |
| 6 - Milk   | 12 - Calculated by ourselves   |

The figures show that for the practical purposes of sanitary-hygienic appraisal of natural activity, it is sufficient to determine the concentration of potassium in the environmental objects with subsequent calculation of K-40 activity.

We investigated the potassium content of soil samples, vegetation, some food products, sheep organs and tissues, and human excretions. The potassium concentration was determined by the volumetric tetraphenylborate method, the principles of

which are described by A. T. Iyevin'sh and E. Yu. Gudrinyetas.

According to the authors, the precipitate of potassium tetraphenylborate  $K[B(C_6H_5)_4]$  does not dissolve even in decinormal acids, and the presence of such ions as  $Li^+$ ,  $Mg^{2+}$ ,  $Ca^{2+}$ ,  $Ba^{2+}$ ,  $Cl^-$ ,  $SO_4^{2-}$ ,  $NO_3^-$ ,  $PO_4^{3-}$ ,  $UO_4^-$ , etc. does not interfere with the determination of the potassium content.

In the soil samples we determined the total potassium content, fusing them for this purpose with NaOH and  $Na_2CO_3$ . We leached the soil with 6N HCl to determine the concentration of the so-called "available" potassium. (In soil science the "available" amount of an element is that portion which is washed out of a soil sample by 6N HCl. It is this portion which largely participates in biological metabolism).

A batch of air-dried soil (1 g) was roasted in a muffle furnace at 500-600° until the organic substances were burned out. Then small amounts were placed in a nickel crucible with the melted NaOH (3 g) to which 0.2 g of  $Na_2CO_3$  was added; the fusion was continued in the muffle furnace 1/2 to 1 hour. The resultant product was extracted with 40 to 50 ml of hot distilled water and immediately passed through a Büchner funnel. The volume of filtrate ( $V_2$ ), 5 ml of it ( $V_3$ ) was measured, neutralized with concentrated  $HNO_3$ , and 5 ml of 0.2 n  $HNO_3$  solution added. The precipitated silicate was removed by



filtration in a Buchner funnel. Then 2 ml of 3% aqueous solution of  $\text{Na[B(C}_6\text{H}_5)_4]$  was added along with 1 ml of 0.1 M solution of  $\text{Al(NO}_3)_3$  for better coagulation. The precipitate was removed in a Schott No. 4 funnel, washed with saturated solution of  $\text{K[B(C}_6\text{H}_5)_4]$  and then with a little distilled water, and dissolved in 10 ml of acetone.

Added to the acetone solution of  $\text{K[B(C}_5\text{H}_5)_4]$  5 ml of 2 N  $\text{CH}_3\text{COOH}$  solution, 1 ml of 0.1 N KBr solution, and 2 drops of a 1% solution of eosin. Titration was done with 0.05 N  $\text{AgNO}_3$  solution until the yellow-red color turned red-violet. The amount of potassium in grams per kg of soil (Q) was calculated from the formula

$$Q = \frac{(V_1 - 2)V_2 \times 1.955}{V_3 P}$$

where  $V_1$  is the volume of 0.05 N  $\text{AgNO}_3$  solution (in ml);  $V_2$  is the volume of soil sample solution (in ml); 2 is the volume of 0.05 N  $\text{AgNO}_3$  solution required for titrating the 1 ml of 0.1 N of KBr solution added; 1.955 is the amount of potassium (in mg) equivalent to 1 ml of 0.05 N  $\text{AgNO}_3$  solution;  $V_3$  is the volume of soil sample solution taken for precipitation of the potassium (in ml); P is the batch of soil sample (in g).

In analyzing the potassium content of liquid biological objects (milk, blood, urine), 150-200 ml of the latter were

evaporated in porcelain beakers in a sand bath with 2 ml of concentrated  $\text{HNO}_3$  added. The solid residue was calcined at 500-600°. Batches of other objects (plants, grain, bones and soft tissues of sheep, excrement) were first dried in an electric stove and then calcined under the same conditions. 500 mg of ash was processed in a porcelain dish with 2 ml of concentrated  $\text{HNO}_3$  and (in drops) 1 ml of 30%  $\text{H}_2\text{O}_2$  solution. The mixture was carefully (to avoid spattering) dried over an electric stove and roasted in a muffle furnace. This operation was repeated until the ash turned white or slightly reddish. 3 ml of concentrated  $\text{HCl}$  and 1 ml of concentrated  $\text{HNO}_3$  were added to the cooled mineral residue and the mixture evaporated. Then 2 more ml of  $\text{HNO}_3$  was added and the mixture again evaporated to dryness. The contents of the dish were dissolved in 5-10 ml of 0.1 n  $\text{HNO}_3$  solution. The amount of potassium in the solution was determined by the above-described method.

The results of the investigations were statistically processed and the arithmetic mean and the standard deviation ( $\bar{M} \pm m$ ) determined. The figures are shown in Table 3.

**Table 3**

**Potassium Content and Radioactivity of Certain Environmental Objects due to K-40**

| Name of object                    | No. of samples | Potassium content (in g/kg and in g/l) | Activity due to K-40 in $10^{-5}$ (in curies/kg) |
|-----------------------------------|----------------|--|--|
| <u>Soil</u>                       |                |  |  |
| 0-1 cm layer . . . . .            | 18             | $2.50 \pm 0.20$                        | $1.02 \pm 0.16$                                  |
| 1-5 cm layer . . . . .            | 11             | $1.50 \pm 0.20$                        | $1.21 \pm 0.16$                                  |
| 0-5 cm layer (fusion) . .         | 23             | $17.7 \pm 0.34$                        | $14.4 \pm 0.27$                                  |
| <u>Plants</u>                     |                |  |  |
| Green steppe grass . . .          | 12             | $2.16 \pm 0.56$                        | $1.70 \pm 0.40$                                  |
| Hay (shrinkage factor 4,6)        | 24             | $10.3 \pm 1.60$                        | $8.40 \pm 1.22$                                  |
| Sedge . . . . .                   | 5              | $4.96 \pm 1.90$                        | $3.90 \pm 0.73$                                  |
| Cereal grasses . . . . .          | 6              | $0.87 \pm 0.12$                        | $0.70 \pm 0.10$                                  |
| Nettle, grasses . . . . .         | 7              | $4.40 \pm 0.50$                        | $3.56 \pm 0.40$                                  |
| Potato (tubers) . . . . .         | 6              | $3.96 \pm 0.10$                        | $3.15 \pm 0.08$                                  |
| wheat (grain) . . . . .           | 14             | $3.80 \pm 0.20$                        | $3.10 \pm 0.16$                                  |
| <u>Food products</u>              |                |  |  |
| wheat bread . . . . .             | 10             | $1.60 \pm 0.10$                        | $1.30 \pm 0.08$                                  |
| Cow's milk . . . . .              | 172            | $1.20 \pm 0.04$                        | $0.97 \pm 0.03$                                  |
| <u>Sheep organs &amp; tissues</u> |                |  |  |
| Hide with wool . . . . .          | 10             | $5.90 \pm 0.30$                        | $4.75 \pm 0.25$                                  |
| Stomach . . . . .                 | 10             | $1.65 \pm 0.10$                        | $1.35 \pm 0.08$                                  |
| Small intestine . . . . .         | 10             | $1.35 \pm 0.15$                        | $1.25 \pm 0.12$                                  |
| Large intestine . . . . .         | 10             | $1.55 \pm 0.10$                        | $1.25 \pm 0.08$                                  |
| Liver . . . . .                   | 17             | $2.56 \pm 0.17$                        | $1.96 \pm 0.14$                                  |
| Kidneys . . . . .                 | 10             | $1.50 \pm 0.12$                        | $1.21 \pm 0.10$                                  |
| Spleen . . . . .                  | 10             | $3.50 \pm 0.27$                        | $2.84 \pm 0.22$                                  |
| Lungs . . . . .                   | 10             | $1.55 \pm 0.14$                        | $1.23 \pm 0.12$                                  |
| Heart . . . . .                   | 10             | $1.70 \pm 0.18$                        | $1.38 \pm 0.15$                                  |
| Skull bones . . . . .             | 31             | $1.30 \pm 0.21$                        | $1.05 \pm 0.17$                                  |
| Thigh bones . . . . .             | 58             | $1.60 \pm 0.12$                        | $1.30 \pm 0.10$                                  |
| Ribs . . . . .                    | 32             | $1.40 \pm 0.17$                        | $1.13 \pm 0.14$                                  |
| Muscles . . . . .                 | 26             | $2.14 \pm 0.13$                        | $1.73 \pm 0.10$                                  |
| Blood . . . . .                   | 14             | $0.58 \pm 0.08$                        | $0.47 \pm 0.06$                                  |
| <u>Human excretions</u>           |                |  |  |
| Urine . . . . .                   | 285            | $1.35 \pm 0.04$                        | $1.09 \pm 0.03$                                  |
| Feces . . . . .                   | 247            | $4.00 \pm 0.12$                        | $3.24 \pm 0.10$                                  |

Note: Activity due to K-40 (A) calculated from the formula:  
 $A = 8.1 \cdot 10^{-10} Q$ , where Q is the potassium content of the sample  
 (g per kg) and  $8.1 \cdot 10^{-10}$  is the specific activity of potassium  
 in curies/g).

Analysis of the potassium content of light chestnut, chestnut, and saline chestnut soils failed to reveal any differences between them with respect to the amount of this element. Therefore, all the data on these varieties of soils are combined into a single group. Table 3 shows that the content of "available" potassium in soils is about 10% of the total obtained by the fusion method. It will be noted that the top layer of soil (0-1 cm) contains 25% more potassium than the lower layers.

As for the grasses, the maximum potassium concentration (4.9 g per kg) was found in sedge, the least in the cereals. The steppe grass with a predominance of cereals contained 2.1 g per kg on the average. Potatoes and wheat had the same amount (3.9 and 3.8 g per kg). Wheat bread contained 2.37 times less potassium than did wheat, which may have been partly due to the change in weight on baking. The insignificant differences in the potassium content of the various samples of milk is noteworthy (172 samples,  $M=1.21$  g/l,  $m=0.04$ ).

Sheep blood contained 0.56 g/l of potassium on the average. The element was distributed fairly uniformly in sheep bone (1.5-1.6 g per kg). The muscles and liver had more than bone. By using the figures of potassium content of the bones and muscles of sheep it is easy to calculate its concentration in

mutton, which (with average fattening of sheep) consists of 22.6% bone and 75.9% muscle. The rated amount of potassium in this "standard" meat is 1.74 g per kg, and its natural activity is  $1.28 \cdot 10^{-9}$  curies/kg.

Our data on potassium in human excretions indicate that the mean daily elimination of the element (with mean daily feces of 400 g and urine of 1.5 l) is 3.65 g (or in K-40 activity -  $2.94 \cdot 10^{-9}$  curies). This amount of potassium apparently is ingested daily with food, if there is such a thing as a potassium balance.

It will be noted that the area from which the samples were obtained does not have a high natural radiation background. Therefore, the values we obtained may serve to characterize the natural radioactivity of the environmental objects examined. They can be used for rough appraisals of the extent to which natural radioactivity exceeds the natural background. More accurate appraisals would require application of the method of isolating potassium from environmental objects described in this paper.

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RECORDING OF PHYSIOLOGICAL FUNCTIONS IN MAN WHILE  
PERFORMING PHYSICAL WORK

[Following is a translation of an article by R. L. Rabinovich in the Russian periodical Gigiyena i Sanitariya (Hygiene and Sanitation), Vol. 27, No. 9, 1962, pages 85-90.]

The complex process of functional changes in man and the different rates at which they are restored make it impossible to appraise the changes that take place during work from the data obtained after it ceases, i.e., in the restoration period. This has naturally impelled the physiologists to try to record changes during work. The effort has been more or less successful in connection with the indices of pulmonary gaseous exchange. However, the determination of such an apparently easily accessible index as pulse rate has proved to be extremely difficult.

In the light of the foregoing, we attempted to review the methods available to evaluate the state of various human physiological functions in certain kinds of activity. The apparatus used for this purpose can be divided into two main groups. One involves the use of a pickup attached to the subject's body and a recording part connected by wires.

The other group of instruments operates on the principle of radio transmission of signals from subject to experimenter. The weight

and size of the transmitter vary with the extent to which the worker's body moves. If the distance is slight, the radio transmitter can be set near the subject and connected with the appropriate pickups and wires. If, however, the recording is done while the subject moves about freely, it is important that the transmitter be small and light; otherwise it could not be attached to the subject or it would interfere with his activity. And, finally, there is a small group of instruments based on the recording of mechanical shifting of parts of the instrument rather than on recording of electrical impulses.

Electrical impulses to be recorded have different origins. Some arise directly in the body and they must be received and recorded (e.g., electrocardiogram (EKG), electroencephalogram (EEG), electromyogram (EMG), etc.). Others arise as a result of the transformation of mechanical or luminous energy (e.g., by the piezoelectric effect or use of photocells). Still others are caused by a change in the parameters of the electric current that supplies the pickup (e.g., change in resistance). The working principle and purpose of medical electric measuring and recording devices are described in G. A. Smirnov's monograph (1956).

Some authors investigated the performance of physical work when the subject's movements were restricted and the



pickup and recording part of the instrument were connected by wires. This technique was used to study the respiratory rate (B. A. Alpat'yev, I. N. Kondrat'yeva, and G. V. Minayeva, 1959; B. A. Alpat'yev and I. N. Kondrat'yeva, 1959; others), cardiac rate (A. Arutsev, 1959; V. V. Mikhaylov and V. L. Fedorov, 1959; others), electrocardiograms (L. A. Vodolazskiy, 1958; A. A. Biryukovich, V. M. Korol', and V. S. Farfel', 1960); electroencephalograms (A. I. Roytbak and B. V. Tavartkiladze, 1953), and electromyograms (L. A. Vodolazskiy, 1958; A. A. Biryukovich, V. M. Korol', and V. S. Farfel', 1960; others).

Study of the above-mentioned works reveals that most of the authors recorded the changes taking place in some system, mostly the cardiac rate, during muscular activity. Only a few investigators recorded the indices of the functional state of several systems simultaneously. This was due to serious difficulties of methodological nature arising in connection with the attempt to make such recordings. Several authors proposed the use of special electrodes and means of securing them to the subject's body, frequency filters, and other devices enabling the experimenter to isolate the impulse of the electric current in which he is interested from all the others caused by the activity of other organs and systems or resulting from surrounding electrical influences (induction currents). A. Arutsev

(1958) investigated the cardiac rate while the subjects were lifting weights or running 100 m. The author judged the pulse rate from the action currents of the heart.

Some methods of recording the pulse rate are not based on the action currents of the heart but on another principle. For example, M. Ye. Marshak (1956) proposed the use of piezo pickups for this purpose, one to measure the pulse in the blood vessels of a finger, the other to do so in an ear lobe. He used the device to investigate work on an ergometer bicycle and determined the static exertions of humans.

V. V. Mikhaylov and V. L. Fedorov (1959) recorded the pulse rate by means of a pickup with photocell attached to the pinna. This pickup can be used when performing work that does not involve moving the head (work on an ergograph, ergometer bicycle, static exertions). The authors found that the pulse rate is 178 to 220 beats per minute during intense work.

Attempts have been made to obtain data not only on the state of the cardiovascular and respiratory systems during work but also on thermoregulation. For example, P. I. Gumener, Ye. F. Kuznetsov, and A. B. Rodov (1958) were able to record changes in the skin and body temperatures of workers under industrial conditions. Pickups were fastened to special belts worn by the men. L. A. Vodolasskiy (1958) also conducted research under industrial conditions (cold processing of metal). His work

differs from the others in that he recorded two indices simultaneously - the action currents of the heart and skeletal muscles. The author overcame many difficulties caused by the presence of induction currents in the shop and by grounding of the subject through the metal object to be processed.

The work of A. I. Roytbak and B. V. Tavartkiladze (1953) is even more complete. The authors studied the electrical activity of the cerebral cortex, respiration, and heart during muscular work, particularly during the "dead point". The subjects performed an assigned task on an ergometer bicycle. The authors had previously worked out objective indications for the onset of the "dead point". In the present investigation they found that the cardiac rate increased steeply from the start of exercise to 180-200 beats per minute at the onset of the "dead point". The cardiac rate is quite unsteady throughout this state. Then, with the second wind, the pulse remains the same or becomes somewhat more rapid than before the "dead point". When the work is finished, the pulse slows a few seconds later, not at once. Respiration after cessation of work, however, slows immediately. The authors report one fact that surprised them. During work the alpha rhythm was recorded on the EEG, despite the noise of the ergometer bicycle. This phenomenon kept recurring during the entire "trip",

except when the subject was in the "dead point" state, at which time the alpha rhythm disappeared.

The investigations mentioned above involved adult athletes or workers. However, children may also be appropriate subjects. The research of A. A. Biryukovich, V. M. Korol', and V. S. Farfel' (1960) on school children 8 to 14 years of age is interesting in this connection. By simultaneously recording three indices - amplitude of squats and action currents of the heart and skeletal muscles - they were able to detect the initial but clear signs of fatigue.

Such are the methods and some of the information obtained by using apparatus based on the pickup and recording part being connected by wires. However, the recording of physiological functions under similar conditions, i.e., with limited body movement of the subject, can also be done by radio instruments. Aviation and space medicine have made extensive use of radio communication in research on animals and human beings. Scientists recorded electrocardiograms, blood pressure, respiration, and motor activity in the dog Layka while traveling in the second Soviet earth satellite. They have also recorded the state of physiological functions in animals during the flights of the later satellites and rockets and in the cosmonauts Yu. A. Gagarin and G. S. Titov. The microclimate of the capsules in which the latter traveled was likewise recorded.

There are some data in foreign literature on high-altitude flights. Glascock and Holfer (1952) observed animals flying in high-altitude rockets. Skano (1955) reported on changes in the physiological functions of pilots. EEGs, EKGs, and EMGs have been recorded by radio (Barr, 1954; Glascock and Holfer (1952); Parker, Brickel, and Christopherson, 1953).

The few but convincing facts reported in the literature indicate that there is a genuine possibility of recording certain physiological functions during the performance of muscular work. However, these facts were obtained, as noted above, with apparatus designed to make such recording only in the case of slight body movements of the subject. Let us now consider the research techniques and information obtained from investigations of freely moving persons.

Some investigators (V. V. Kuz'min, 1958) designed instruments based on mechanical force (e.g., to record respiration). Their governing principle is as follows. Air set in motion by breathing is impelled by a mask or mouthpiece through a rubber tube to a Murray capsule connected to a writing pen. The timer and paper tape are started by a clock. The weight and size of these instruments is small so that they are easily worn by the subject as he moves about doing muscular work.

The authors analyzed the data obtained with respect to both

the rate and nature of the respiration. They determined the duration of the respiratory phases and some other indices.

V. K. Solov'yev thinks that the resultant curves can be used to judge the magnitude of pulmonary ventilation. One of the main defects of these devices is that they are very inert due to the rigidity of the rubber capsule.

Electronics is coming into increasing use in medicine. It is broadening and raising the technique level of research, as can be seen in the papers read at a conference dealing with this subject (A. I. Berg, 1960).

Miniature radio transmitters are providing invaluable help in solving many of the problems confronting us. For example, L. Bagan (1955) recorded respiration during physical work and running. In 1956, the same author and I. Lovdshiyev succeeded in recording the volume of pulmonary ventilation by radio. There are also data on radio recording of the biocurrents of freely moving persons. A number of Soviet investigators have been working on the problem of recording the cardiac rate by radio (V. V. Rozenblat and L. S. Dombrovskiy, 1957, 1956, 1959, 1959a; V. V. Rozenblat, 1959, 1960). Rozenblat and Dombrovskiy designed an instrument which they called a "radiopulsophone". The biocurrents of the heart are used to calculate the pulse rate. The "subject's instrument" consists of a pickup, power supply, and radio transmitter.

The "experimenter's instrument" may be any ultrashortwave radio receiver (88-42 megacycles per second). The recording may be phonic, graphic, or loop. The instrument is mounted on a helmet worn by the subject. The power source weighs 150 g, the entire apparatus 350 g. The communication distance is 500 m. This apparatus was used to obtain information on the pulse rate of skaters. A pulse rate of 220-230 beats per minute was recorded during 500-3000 m sprints. The finish peak was noted when the distance was covered, at which time the pulse decelerated very rapidly.

A. P. Sarychev (1959, 1959a, 1960) used radiotelemetering apparatus to record electromyograms and other electric phenomena through sound signals on magnetic tape. The investigations were conducted chiefly on carmen.

G. V. Unzhina and V. V. Rozenblat (1959) described a pickup for recording respiration in freely moving persons. They utilized the principle of change in capsule resistance with powdered coal which results from chest movements.

The interesting research of V. P. Pravosudov (1960) provides information on the cardiac rate in cyclists during training, warming-up periods, and contests. The author presents data on the pulse rate per 10 seconds. At rest it was 13-15 beats. When the athlete mounted the bicycle it

quickened to 19-21 beats. In the warm-up period (by the end of the first minute) it was 25-26 beats. The author found that the pulse rate varied with the speed of movement, achieving 31 beats per 10 seconds. During the first 10 seconds after the distance was covered the rate did not change. It then slowed to 1 beat per 10 seconds but quickened to 25-26 beats by the end of the first minute. The pulse rate took more than 15-20 minutes to return to normal.

P. I. Gumener and S. A. Poltarak (1960) designed an instrument to record changes in the temperature of the skin, body, and clothing. It permits measurements to be made accurate to 0.1° and is portable (weighing 200 g). Its range is 600 m.

It is frequently necessary to record several functions simultaneously. This can be done with the apparatus designed by L. P. Shuvstov (1959). The author describes a three-channel instrument (1959a) that makes it possible to record the pulse, respiration, and muscle biocurrents in children at one time. The transmitting part weighs 150 g. Z. S. Uvarova (1959) used the apparatus to study children 2-3½ years of age while they were performing physical exercises.

Very few human physiological functions have been recorded during the performance of muscular work and only a few invest-



igators have done research in the field. Yet the available experimental data, although not abundant, reveal that the application of the methods described in this paper holds great promise in research both on adults and on young children.

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## BETA RADIOACTIVITY OF LUGANSK OBLAST WATERS

[Following is a translation of an article by G. S. Gan and P. F. Tashchi in the Russian periodical Gigiyena i Sanitariya (Hygiene and Sanitation), Vol. 27, No. 9, 1962, pages 98-99.]

During 1959-1960 we analyzed the water in open bodies of water and subterranean sources located in Lugansk oblast for content of beta-active substances. We obtained 197 samples, including 75 water, 72 bottom deposits, 26 aquatic plants, 24 fish, from the Northern Don River and its tributaries, the Aydar, Derkul, Lugan', and Bol'shaya Kamenka.

Beta radioactivity was determined after preliminary treatment of the samples (evaporation, drying, calcination). We used B-2 radiation meters and MST-17 end-window counters. The complexity and laboriousness of radiochemical investigation of objects with very low total radioactivity initially limited our efforts to determination of just the beta activity. The data on range of fluctuations of beta activity are shown in Table 1. The characteristics of the beta radioactivity of the bottom deposits are shown in Table 2.

There is known to be a dynamic equilibrium between the activity of water and the activity of bottom deposits. A change in this equilibrium in any direction is due to several factors, including the nature of the bottom deposits.

Table 1

| Body of water               | Range of beta activity of dry residue (in c/l) |
|-----------------------------|--|
| Northern Don                | $1 \cdot 10^{-12}$ — $3,4 \cdot 10^{-11}$      |
| Aydar                       | $9,4 \cdot 10^{-12}$ — $9,3 \cdot 10^{-11}$    |
| Derkul                      | $1 \cdot 10^{-12}$ — $4,9 \cdot 10^{-11}$      |
| Lugan'                      | $1 \cdot 10^{-12}$ — $1,9 \cdot 10^{-11}$      |
| Bol'shaya Kamenka           | $1 \cdot 10^{-11}$ — $3,4 \cdot 10^{-11}$      |
| Don (mouth of Northern Don) | Less than $1 \cdot 10^{-12}$                   |

Table 2

| Body of water               | Range of beta activity of bottom deposits (in c/kg of dry weight) |
|-----------------------------|---|
| Northern Don                | $3,2 \cdot 10^{-9}$ — $3,5 \cdot 10^{-3}$                         |
| Aydar                       | $1,1 \cdot 10^{-8}$ — $2,5 \cdot 10^{-3}$                         |
| Derkul                      | $1,0 \cdot 10^{-8}$ — $2,1 \cdot 10^{-3}$                         |
| Lugan'                      | $8,3 \cdot 10^{-9}$ — $1,2 \cdot 10^{-3}$                         |
| Bol'shaya Kamenka           | $1,4 \cdot 10^{-8}$ — $9,8 \cdot 10^{-3}$                         |
| Don (mouth of Northern Don) | $9 \cdot 10^{-9}$   |

The data show that silty bottom deposits generally possess greater beta activity than sandy deposits with equal activity of the water near them. For example, in portions of the Aydar River with water activity of  $9.4 \cdot 10^{-12}$  —  $3.1 \cdot 10^{-11}$  c/l, sandy bottom deposits had an activity of the order of  $4.0 \cdot 10^{-12}$  as compared with an activity of  $1.2$  —  $1.7 \cdot 10^{-8}$  c/kg of dry weight for the silty bottom deposits. The water activity of the Northern Don was  $1.5 \cdot 10^{-11}$  c/l, while the activity of the sandy bottom deposits washed by it was  $6.2 \cdot 10^{-12}$  c/kg of dry weight; water activity of  $1.0 \cdot 10^{-12}$  c/l compared with an activity of  $2.5 \cdot 10^{-8}$  c/kg of dry weight for the sandy bottom deposits washed by it.

Increasing water activity was sometimes associated with increasing activity of plankton (same kind). For example, in some portions of the Aydar River with water activity of  $1.0 \cdot 10^{-11}$  c/l, activity of the algae was  $9.9 \cdot 10^{-9}$  —  $1.6 \cdot 10^{-8}$  c/kg of dry weight, whereas in the portions with water activity of  $2.6 \cdot 10^{-11}$  c/l, activity of the algae was also higher —  $2.5$  —  $2.7 \cdot 10^{-8}$  c/kg of dry weight.

As water activity increased, activity of the silty bottom deposits rich in organic matter likewise increased.

In portions of the Lugan' River with water activity of  $2.1 \cdot 10^{-12}$  c/l, activity of the bottom deposits was  $8.3 \cdot 10^{-9}$  c/l;

in portions with water activity of  $1 \cdot 10^{-11}$  c/l, activity of similar bottom deposits was  $1.2 \cdot 10^{-8}$  c/l of dry weight (i.e.,  $1\frac{1}{2}$  times more).

Aquatic plants possessed beta activity of about  $3.7 \cdot 10^{-8}$  c/kg of dry weight. Radioactivity of fish in these waters ranged from  $1.5 \cdot 10^{-9}$  to  $2.1 \cdot 10^{-9}$  c/kg of dry weight. Aquatic plants (same kind) exhibited a direct relationship between their content of beta-active substances and the activity of the bottom deposits (only if silty). Beta activity of the algae was mostly determined by that of the water.

The range of fluctuations in activity of water, aquatic plants, and fish is of interest. The greatest range of water activity was observed in the Northern Don where the maximum was 25-35 times higher than the minimum. Radioactivity of the bottom deposits fluctuated less. For example, the maximum activity of the bottom deposits in the Northern Don exceeded the minimum activity 10-12 times. Activity of the aquatic plants fluctuated even less, e.g., 7-8 times in the Northern Don. The smallest changes in activity were noted in the fish, the maximum exceeding the minimum only 1.2-1.5 times.

Some 195 samples were obtained from subterranean water supplies, and in 136 of them beta activity of the dry residue did not exceed  $10^{-11}$  c/l.

Although the data are insufficient to draw conclusions as to changes in the radioactive equilibrium between the water and the biomass at different times of the year, some of the findings tend to show that there is some increase in radioactivity of the biomass in the summer and a decrease toward the end of fall.

It is evident from the data presented in this communication that the waters of the Northern Don, its tributaries, and subterranean sources located in Lugansk oblast possess comparatively low beta radioactivity.

CHANGES IN CORTICAL AND SUBCORTICAL REACTIONS IN CHILDREN  
DURING MENTAL FATIGUE AND ITS ELIMINATION BY COLD  
AGENTS AND PHYSICAL EXERCISE

[Following is a translation of an article by Yu. M. Pratusovich and L. N. Shustruyskaya in the Russian periodical Gigiena i Sanitariya (Hygiene and Sanitation), Vol. 27, No. 9, 1962, pages 103-109.]

Several years ago we used the classical secretory-motor method of conditioned reflexes to discover and describe prolonged inhibited phases in the cerebral hemispheres developing in children during mental fatigue (Pratusovich, 1956). The secretory conditioned reflexes revealed regular impairment of correct intensity relations in conditioned responses in school work ranging from 8 to 11 hours a day. We were able to overcome the fatigue and restore optimum excitability by reducing the school load by three hours a day through cutting down on homework. The length of time the children could stay outdoors was increased proportionately (Pratusovich, 1955).

During the next few years study of brain activity in children by the classical conditioned reflex method (analysis of brain work by horizontals was supplemented by study of the dynamics of reactive brain potentials (analysis by verticals). Using a modification of Lovell and Dossett's method of reactive potentials, we discovered the existence of changes in electric



reactivity of the brain during mental fatigue and described the laws governing these changes (Yu. M. Pratushevich and N. N. Korzh, 1961).

The main tendency in the work of the fatigued brain of children, as our research showed, is for the synchronization factor and energy of the reactive potentials to increase. In our studies on the reactive brain potentials of children with a block of the adrenergic and M-cholinergic structures in the synapses of the reticular formation of the brain stem, we found that the synchronization factor and energy of reactive potentials increase upon deterioration of synaptic transmission in the activating division of the reticular formation. The main purpose of our research was to overcome children's fear and pain in otolaryngological operations under local anesthesia by means of central ganglion blocking drugs. At the same time it convincingly demonstrated the existence of changes in electric reactivity of the brain after exclusion of reticular formation structures, sharp weakening of their activating influence, and development of marked sleepiness in the children. Comparing the bioelectric reactivity of children during mental fatigue with the reactivity when one of the two pathways of transmission of nerve impulses (adrenergic or cholinergic) in the reticular formation is blocked, we found that changes in the reactive potentials of the brain coincided (G. N. Speranskiy and

Yu. M. Pratusovich, 1961a, 1961b).

Analysis of our findings led us to conclude that there are inhibited states (hypnotic phases) in the cerebral hemispheres and a low level of synaptic transmissions of the ascending activating system of the reticular formation during mental fatigue. The following questions then arose: what is the nature of the cortical-subcortical relations during mental fatigue? Can mental fatigue be overcome by using natural (and therefore harmless) reflex factors?

In investigating cortical-subcortical relations in children we used a new comprehensive method of studying higher nervous activity. N. I. Krasnogorskiy's device for recording secretory-motor conditioned reflexes was attached to a 15-channel Alvar electroencephalograph and a special spooling mechanism wound the paper tape at the rate of 3 mm per second. This technique was modified and supplemented with a parallel recording of three other nonspecific autonomic components of the food reaction: (a) respiration recorded with a piezoelectric pickup; (b) digital plethysmogram obtained with the aid of a special Alvar photoelectric plethysmographic attachment called a "plethysmovar" (the amplitude of the plethysmogram recorded is inversely proportional to the magnitude of vasodilatation); (c) galvanic skin reaction (GSR) recorded, like all the other reactions, by means of the dc amplifier of the electroencephalograph.

If food (motor and secretory) conditioned reflexes mirror chiefly the cortical level of these reactions, then the motor, vascular, and galvanic skin components of the food reaction reflect its subcortical level. The above-mentioned complex polygraphic recording of five components of the food reaction enabled us to make a deeper and fuller study of cortical-subcortical relations in 12-15 year old children. More than 500 investigations were conducted on 18 healthy children living under the same conditions in a boarding school.

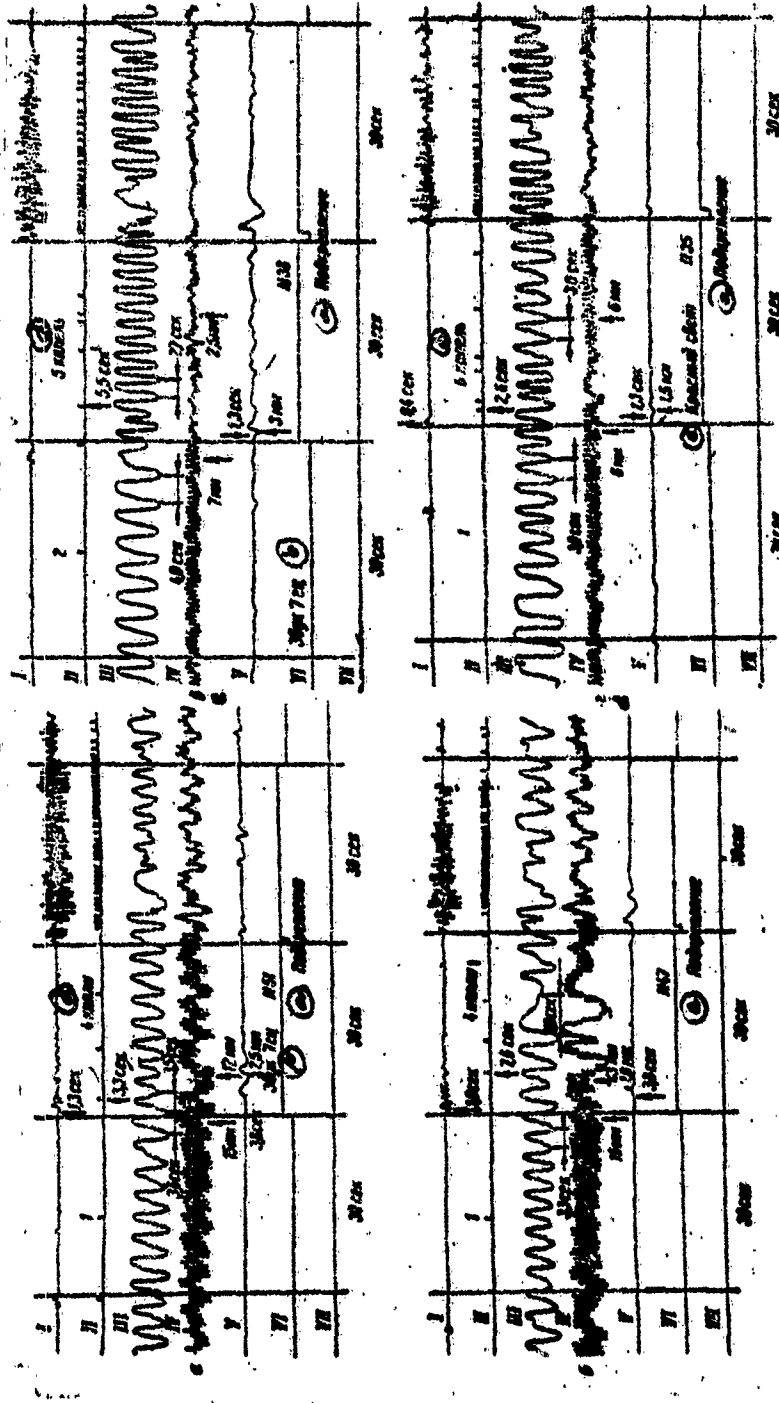
Our experiments showed that it is difficult to form a dynamic stereotype during mental fatigue. Secretory conditioned reflexes are formed with great difficulty, their intensity relations are impaired, and they do not conform to Pavlov's "law of intensity". The dynamic stereotype is characterized on the whole by an extreme instability and low level of conditioned reflexes. The autonomic components of the food conditioned reflex are likewise indicative of inhibited states in the brain at the level of the subcortical formations and reticular formation. The autonomic reactions are quickly and completely extinguished (GSR) or become very faint after several tests (vascular, respiratory). We observed similar phenomena with an amixil block of the *M*-cholinergic structures of the central synapses of the reticular formation. Such a block com-

pletely extinguished the orienting GSR to intermittent light, which was restored two hours after the drug was administered (G. N. Speranskiy and Yu. M. Pratusovich, 1961b).

Let us now examine in detail the kymograms reflecting cortical-subcortical relations during mental fatigue after 5-6 hours of class work. Fig. 1 shows that conditioned responses to a strong stimulus (intermittent sound of 7 cps) and to a weak stimulus (red light) by Tanya Ts. are the same and amount to 4 drops (Fig. 1a, b). We see here a balancing inhibited phase in the cerebral cortex. The autonomic components, as revealed by the kymogram, are likewise absent: vascular and respiratory reactions unchanged, GSR insignificant. Tolya M. exhibits a paradoxical reaction of conditioned salivation (to sound - 5 drops, but to the red light - 6 drops), insignificant GSR (Fig. 1c, d).

To increase the tone of the subcortical formations and cerebral cortex that was lowered by fatigue resulting from sustained mental work in class, we stimulated the receptors of facial skin and of the pinnae with a cold agent (10° water, with which the children washed themselves for half a minute). It is common knowledge that cold water helps to bring a person out of a faint or sober up a drunk. History tells of many great men who used cold water to increase their functional

Fig. 1. Comprehensive Investigation of Higher Nervous Activity after Mental Work in Class



a - Tanya Ts.'s reaction to a conditioned stimulus - sound with a frequency of 7 cps (experiment of December 21, 1960); b - Tanya Ts.'s reaction to a conditioned stimulus - red light - in the same experiment; c - Tanya M.'s reaction to a conditioned stimulus - sound with frequency of 7 cps (experiment of May 15, 1961); d - Tanya M.'s reaction to a conditioned stimulus - red light - in the same experiment.

I - motor reaction; II - secretion; III - respiration; IV - plethysmogram; V - galvanic skin reflex (GSR); VI - conditioned stimulus and reinforcement; VII - time marker (30 seconds)

a) Reinforcement  
b) sound 7 cps

c) Red light  
d) drops

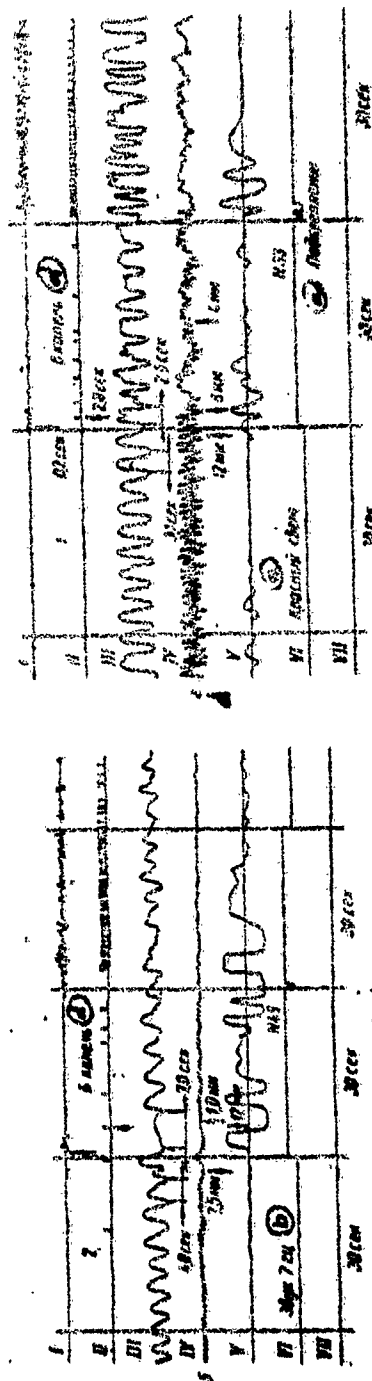
e) Green light  
cek = sec

capacity. For example, General A. V. Suvorov and Victor Hugo poured cold water on themselves before starting to work, and Pushkin took morning ice baths. The cold stimulus caused changes in the electric reactivity of the brain (desynchronization) of the children in the direction of decreased energy of the reactive potentials (G. N. Speranskiy and Yu. M. Pratusovich, 1961c). Application of the cold stimulus to the facial receptors overcame their fatigue and gave them a feeling of cheerfulness and freshness. At the same time it sharply increased the tone of the subcortical formations and then that of the cerebral cortex. Increased tone of the subcortical formations was manifested in restoration of all the autonomic components of the food reflex (especially the vascular and galvanic skin reactions). There was also strong, protracted, and progressive dilatation of the digital blood vessels.

Fig. 2 shows that Tanya Ts.'s secretory conditioned reflexes characterizing the dynamic stereotype increased after application of the cold agent and conformed to the "law of intensity": sound of 7 cps - 9 drops, red light - 6 drops, green light - 1 drop. Higher nervous activity became normal at the cortical and subcortical levels. This is revealed by the fact that the GSR as the autonomic component of the food reflex developed vigorously, its latent period was reduced to

1.6 seconds, the amplitude increased sharply, and spontaneous GSRs appeared frequently. The same is true of the respiratory component. Whereas previously it was unchanged (Fig. 1a), now before application of the conditioned stimulus the respiratory period lasted 3.3 seconds, after application of the stimulus 5.3 seconds (Fig. 2a) and then 4 and 7 seconds, respectively (Fig. 2b). As for the vascular reaction, previously the amplitude of the plethysmogram was 15 and 12 mm (Fig. 1a), but now before the conditioned stimulus it was 8 mm, after it 4 mm (Fig. 2a) and then 2.5 and 1 mm, respectively (Fig. 2b). The same pattern was observed in TolyaM. Instead of a paradoxical reaction characterizing fatigue, the conditioned reflexes increased and conformed to the "law of intensity": to sound of 7 cps - 10 drops, red light - 8 drops, green light - 1 drop. The GSR, barely perceptible before, now strongly increased - from 1.5 to 8 mm to the red light (Fig. 1d and Fig. 2d) and from 3 to 10 mm to the sound (Fig. 1c and Fig. 2c). The vascular response to the conditioned signal likewise increased sharply: to the red light the amplitude was 8 and 6 mm (Fig. 1d), became 12 and 4 mm (Fig. 2d); it was 7 and 2.5 mm to the sound (Fig. 1c), became 16 and 4 (Fig. 2c). On execution of the conditioned reflex the respiratory autonomic component also increased (Fig. 2c, d).

|     | 2012 | 2013 | 2014 | 2015 | 2016 |
|-----|------|------|------|------|------|
| I   | 2012 | 2013 | 2014 | 2015 | 2016 |
| II  | 2012 | 2013 | 2014 | 2015 | 2016 |
| III | 2012 | 2013 | 2014 | 2015 | 2016 |
| IV  | 2012 | 2013 | 2014 | 2015 | 2016 |
| V   | 2012 | 2013 | 2014 | 2015 | 2016 |
| VI  | 2012 | 2013 | 2014 | 2015 | 2016 |
| VII | 2012 | 2013 | 2014 | 2015 | 2016 |



a) Tanya Ts.'s reaction to a conditioned stimulus - sound with a frequency of 7 cps in the first half of the investigation (experiment of December 14, 1960); b) Tanya Ts.'s reaction to the same stimulus in the second half of the investigation (experiment of December 14, 1960); c) Tolya M.'s reaction to a conditioned stimulus - sound with a frequency of 7 cps (experiment of May 12, 1961); d) Tolya M.'s reaction to a conditioned stimulus - red light - in the same experiment.

I - motor reaction; II - secretion; III - respiration; IV - plethysmogram; V - galvanic skin reflex (GSR); VI - conditioned stimulus and reinforcement; VII - time marker (30 seconds)

a) Reinforcement  
b) sound 7 cps  
c) Red light  
d) drops  
e) Green light  
oct = sec



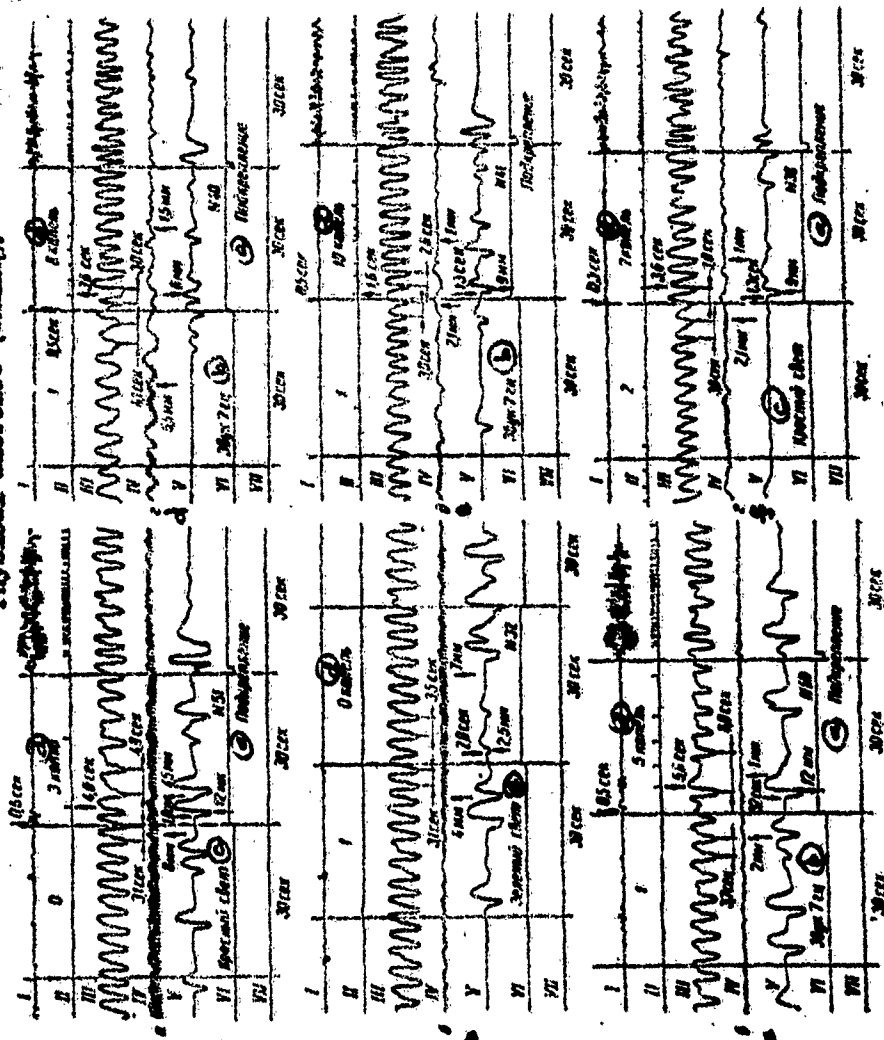
All the phenomena described above testify to increased tone of the subcortical formations and activating division of the reticular formation which executes the autonomic components of the food reaction.

Selye demonstrated experimentally (1956, 1957) that powerful influences on the organism that disrupt the stability of the milieu intérieur bring about a special condition that he called "stress". Stress is associated with a variety of functional changes, sometimes physiological in nature, at other times pathological. The latter occur with very powerful influences or when the organism is weak. What interests us is not the pathological changes that take place in response to strong stimuli (stressors), but the physiological changes that arise after the action of ordinary stimuli and result in the development of "nonspecific increased resistance" (N. V. Lazarev, 1958). The bodily changes resulting from the action of a stressor, which produce what Selye called the resistant stage, have enormous prophylactic significance for children. Nonspecific resistance here increases both to the stimulus itself and to other factors as well. These manifestations have been observed in hypoxia (Z. I. Barbashova, 1955a, 1955b; I. R. Petrov, 1958), after the administration of such drugs as dibazol and ginseng (N. V. Lazarev, 1958, 1960; N. V. Lazarev

and M. A. Rozin, 1960, and after muscular exercise (R. A. Kantarovich, A. Ye. Kaplan, and others, 1956; N. V. Zimkin, 1961). Selye (1956, 1960) states that secretion of the adrenocorticotrophic hormone (ACTH) by the hypophysis and adrenocortical hormones increases under the influence of a stressor. We have observed that the action of such a stress agent as cold is followed by a change in biologically active substances of the blood (epinephrinelike substances, acetylcholine) and decrease in energy of the reactive potentials of the brain (G. V. Speranskiy and Yu. M. Pratusovich, 1961c).

Nevertheless, we do not completely agree with Selye that the endocrine system plays a major role as a protective, physiological, and adaptive reaction in the adaptation syndrome. The action of the stressor is undoubtedly perceived by the primary receptors. The ensuing nervous excitation, as Chang (1957) showed, reaches the cerebral cortex via the specific afferent pathways and the reticular formation via the collaterals. It is through the reticular formation, as Magoun (1960) pointed out, that stress stimuli excite hypothalamic-hypophyseal activity and elaboration of ACTH. Moreover, a stress stimulus like cold stimulates reflexly the activity of the adrenal medulla, which responds by releasing epinephrine into the blood. This takes place, according to M. G.

Fig. 3. Comprehensive Investigation of Higher Nervous Activity after Mental Work in Class and Physical Exercise (Skiing, Basketball).



- a) Reinforcement
- b) sound 7 cps
- c) Red light
- d) drops
- e) Green light
- cek = sec

- a - Tanya Ts.'s reaction to a conditioned stimulus - red light (experiment of February 7, 1961);
- b - Tanya Ts.'s reaction to a conditioned stimulus - green light - in the same experiment;
- c - Tanya Ts.'s reaction to a conditioned stimulus - sound with a frequency of 7 cps in the same experiment;
- d - Tolya K.'s reaction to a conditioned stimulus - sound with a frequency of 7 cps (experiment of May 17, 1961);
- e - Tolya K.'s reaction to a conditioned stimulus - sound with a frequency of 7 cps - in the second half of the same experiment;
- f - Tolya K.'s reaction to a conditioned stimulus - red light - in the same experiment.
- I - motor reaction;
- II - secretion;
- III - respiration;
- IV - plethysmogram;
- V - galvanic skin reflex (GSR);
- VI - conditioned stimulus and reinforcement;
- VII - time marker (30 seconds)

Durmish'yan (1960) at the expense of just a few spinal centers that control the secretion of epinephrine. Epinephrine stimulates in turn the activity of the reticular formation directly as well as reflexly (Dell, Bonvoliet, and Hugelin, 1954). Anderson's experiments (1957) provided convincing proof that stimulation of the reticular formation of the mesencephalon through the hypothalamus intensifies secretion by the anterior lobe of the hypophysis. Data on the relationship between the reticular formation and the central mechanisms of humoral-autonomic adaptation reactions, including the "stress" reaction, can also be found in the works of Koella and Gellhorn (1954). Thus, the humoral factor is one of the links in the reflex mechanism of protective reactions of the organism while the central nervous system (one of whose mechanisms is the reticular formation and the autonomic nuclei of the hypothalamus) has the integrating role.

It is obvious from the foregoing why we chose another stress agent like muscular work (Selye, 1960) as a means of overcoming mental fatigue. Physical exercise for 30-60 minutes in the form of two periods of skiing, basketball, or gymnastics served to increase the tone of the subcortical formations and the cerebral cortex. Fig. 3 shows that Tanya Ts.'s secretory conditioned reflexes completely conformed to the "law of in-

tensity" after two periods of skiing. All the autonomic components were clearly marked, a strong spontaneous GSR appeared, and there was progressive vasodilatation (Fig. 3a-c). The same reactions were observed in Tolya M. after two sessions of basketball: 10 drops of conditioned saliva were secreted in response to the sound, 7 drops to the red light; the GSR was distinct, vasodilatation progressive. The children had a sense of well-being, clear head, and felt cheerful (Fig. 3d-f).

Thus, suitable muscular exercise removes the inhibited phases in the cerebral hemispheres, improves the poor tone of the subcortical nuclei during mental fatigue, and tones up the reticular formation in children.

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